Predictors of Procedural Success and Complications in Percutaneous Coronary Intervention for Chronic Total Occlusions

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Abstract

Objective: To identify the predictors of procedural success and complications in Percutaneous Coronary Intervention (PCI) for Chronic Total Occlusions (CTOs) in patients at Hayatabad Medical Complex, Peshawar, Pakistan.

Methodology: A retrospective cohort study was conducted with 150 patients who underwent PCI for CTO between June 2024 and June 2025. Demographic data, lesion characteristics, procedural details, and complications were analyzed. Statistical analysis included descriptive statistics, chi-square tests, independent t-tests, and multivariable logistic regression to identify predictors of procedural success.

Results: The study found that 48% of patients had procedural success, while 52% had failed procedures. Significant predictors of success included age ($p = 0.04$), J-CTO score ($p = 0.002$), and approach used ($p = 0.01$). Males had a significantly higher procedural success rate compared to females ($p = 0.03$). Logistic regression revealed that younger age (OR = 0.98, $p = 0.03$), lower J-CTO score (OR = 1.5, $p = 0.01$), and antegrade approach (OR = 2.0, $p = 0.05$) were independent predictors of success.

Conclusion: The study concludes that procedural success in CTO PCI is influenced by patient age, lesion complexity, and the approach used. These findings are important for guiding clinical decisions in CTO PCI, suggesting that younger patients with less complex lesions and an ante-grade approach should be prioritized. Future studies with larger, multicentre cohorts are needed to validate these results.

Keywords: Chronic total occlusion, percutaneous coronary intervention, J-CTO score, Procedural success.

Introduction

Percutaneous Coronary Intervention (PCI) has emerged as a pivotal therapeutic modality in managing coronary artery disease, particularly in the context of Chronic Total Occlusion (CTO). CTO represents a significant challenge in interventional cardiology, characterized by a complete blockage of a coronary artery for at least three months. These lesions have traditionally been considered difficult to treat due to their complexity, which often includes factors such as advanced calcification, tortuosity, and the presence of collateral circulation. Despite these challenges, PCI for CTO has gained attraction over the years as a viable option for revascularization, offering substantial improvements in symptoms and quality of life for patients who are refractory to optimal medical therapy.[1]

A significant portion of PCI failures, particularly in CTO cases, can be attributed to procedural complications, which remain a major concern. Studies suggest that while PCI for CTO has been associated with improved outcomes compared to medical therapy, the procedural success rates remain lower than those observed in non-CTO lesions.[2] These complications include

vessel dissection, perforation, and Major Adverse Cardiac Events (MACE), which may compromise patient prognosis. To mitigate such risks, the identification of predictors of procedural success and complications is essential. This is particularly important in regions like Peshawar, where limited data on CTO interventions are available, necessitating a focused exploration of procedural determinants to optimize outcomes in clinical practice.

The background of PCI for CTO has evolved significantly, particularly with advances in techniques and the introduction of specialized devices. Early studies reported low success rates, often below 50%, and high complication rates, especially when compared with other PCI procedures.[3] However, with the advent of more refined techniques, including retrograde approaches, specialized guidewires, and enhanced imaging technologies, success rates have steadily improved. A Research highlighted that procedural success has seen a significant increase over the years, reaching up to 87% in some centres, reflecting improvements in technical expertise and tool availability.[4]

The complexity of CTO lesions—determined by factors such as lesion length, calcification, and vessel tortuosity—plays a crucial role in predicting procedural outcomes.[5] Studies focusing on angiographic and clinical predictors have found that variables such as lesion length and calcium burden are strong independent predictors of procedural failure.[6] Additionally, pre-procedural imaging, including coronary Computed Tomography Angiography (CTA) and Intravascular Ultrasound (IVUS), has proved to be essential in assessing lesion characteristics and planning the most appropriate intervention strategy.[3] This comprehensive approach is critical in predicting procedural success and minimizing complications in CTO PCI.

The role of scoring systems, such as the J-CTO, PROGRESS CTO, and CASTLE scores, has been emphasized in recent literature to stratify risk and predict outcomes .[7,8] These scoring systems assess a combination of clinical, angiographic, and procedural factors, providing valuable tools to interventional cardiologists in determining the likelihood of success for CTO PCI. The J-CTO score, for instance, has been widely validated and is used to predict the difficulty of crossing CTO lesions. It has been shown to have good discriminatory capacity, especially when used by experienced operators.[7]

The patient population also plays a significant role in procedural outcomes. For instance, elderly patients and those with comorbid conditions such as diabetes mellitus or Chronic Kidney Disease (CKD) often experience lower success rates and higher complication rates.[6] The decision-making process becomes more complex when considering patients on haemodialysis, as they present unique risks, including a higher incidence of technical failure and adverse events during CTO PCI.[9] Therefore, patient selection, combined with accurate risk assessment, is fundamental to achieving optimal outcomes.

In light of the rising demand for PCI in patients with CTO, there is an urgent need to further understand the factors that influence procedural success and complications. While numerous studies have been conducted globally, data specific to Pakistan remains limited. This gap is particularly evident in Peshawar, where the medical community would benefit from more localized research. The present study aims to fill this gap by identifying the clinical, angiographic, and procedural predictors of success and complications in CTO PCI at the

Department of Cardiology Hayatabad Medical Complex, Peshawar. This study will not only contribute to the existing body of literature but will also provide practical insights that can guide clinical practice in local settings.

The primary objective of this study is to identify the key clinical, angiographic, and procedural factors that predict the success and complications of PCI for CTOs in patients treated at the Department of Cardiology Hayatabad Medical Complex, Peshawar.

Materials and Methods

Study Design and Setting

This was a retrospective cohort study conducted at the Department of Cardiology, Hayatabad Medical Complex, Peshawar, from June 2024 to June 2025. The study was designed to examine the clinical, angiographic, and procedural factors that could influence the outcomes of CTO PCI, contributing valuable insights to the local population in Peshawar.

Study Sample

The study included 150 consecutive patients who underwent PCI for CTO. The sample size was determined using the WHO formula for prevalence studies, ensuring reliable results with a 95% confidence interval and 5% margin of error, as supported by similar studies.[6]

Inclusion and Exclusion Criteria

Patients who were 18 years of age or older, diagnosed with CTO of a coronary artery, and scheduled for elective PCI were included in the study. Patients with any history of myocardial infarction or coronary artery bypass graft surgery within the past six months, as well as those with concomitant severe heart failure (NYHA class IV), were excluded from the study. Additionally, patients who had contraindications for PCI, such as severe allergies to contrast agents, or those with terminal illnesses or poor prognosis that precluded aggressive interventional treatment, were also excluded. This ensures that only those patients who were expected to benefit from PCI were considered, thereby improving the reliability of the findings.

Sampling Technique

A convenience sampling technique was employed to select patients who had undergone PCI for CTO during the study period. This sampling method was chosen due to the retrospective nature of the study and the availability of medical records within the department. All patients who met the inclusion criteria were identified from the hospital's PCI database and their medical records were reviewed for relevant data.

Data Collection Procedure

Data were retrospectively collected from the medical records of eligible patients. The data collected included demographic information (age, sex, and comorbidities), angiographic details (lesion location, lesion length, calcification, tortuosity, collateral circulation, etc.), procedural details (approach used, guidewire technique, success or failure of the procedure), and complications (including periprocedural myocardial infarction, vascular complications, and bleeding events). Missing data were handled using multiple imputation techniques to strengthen transparency and reduce bias in the analysis. The handling of missing data was done

following established guidelines to ensure that no critical information was omitted from the dataset, maintaining the integrity of the results.

Definitions and Assessment Criteria for Study Variables

The primary outcome was procedural success, defined as achieving a reduction in stenosis of at least 70% without significant complications during the procedure. Secondary outcomes included the incidence of procedural complications, such as periprocedural myocardial infarction, coronary artery dissection, perforation, and major bleeding. Angiographic variables were assessed using the J-CTO score, a commonly used score to predict the complexity of CTO lesions. Complications were classified according to the American College of Cardiology/American Heart Association guidelines for PCI.

Statistical Analysis

Statistical analyses were performed using SPSS version 26. Descriptive statistics (mean, standard deviation, frequency, and percentages) were used to summarize patient characteristics and procedural outcomes. The associations between procedural success and potential predictors were assessed using chi-square tests for categorical variables and independent t-tests for continuous variables. Multivariable logistic regression was used to identify independent predictors of procedural success, adjusting for potential confounders. A p-value of less than 0.05 was considered statistically significant for all tests.

Ethical Considerations

The study was conducted as per the set ethical guidelines and with the approval of Ethical & Research Committee of Hayatabad Medical Complex, Peshawar. The research was conducted in line with principles outlined in the Declaration of Helsinki and thus ensured the protection of the rights and privacy of the patients throughout the investigation. Informed consent was obtained from all participants before data collection began and all participants were entirely voluntary in their participation. The confidentiality of patient information was carefully protected, and all identifying data were not included in the study's reports and publication.

Results

A total of 150 patients who underwent percutaneous coronary intervention for chronic total occlusion were included in the analysis, consistent with the sample size described in the Materials and Methods. The mean age was 53.95±14.486 years, with an age range of 30–79 years. There were 72(48.0%) men and 78(52.0%) women. Procedural success was achieved in 72(48.0%) patients, whereas 78(52.0%) procedures were unsuccessful. Table 1 summarises the demographic, clinical and angiographic characteristics of the study population.

Table 1. Demographic, clinical and angiographic characteristics of the study population

Characteristic	**Overall, N = 150**	**p-value for procedural outcome**
Age, years	53.95±14.486	—
Female	78(52.0%)	0.984
Male	72(48.0%)	0.984
Hyperlipidaemia	37(24.7%)	0.515
No known risk factors	30(20.0%)	0.515

Hypertension	29(19.3%)	0.515
Chronic Kidney Disease	29(19.3%)	0.515
Diabetes	25(16.7%)	0.515
Lesion location: LCX	39(26.0%)	0.549
Lesion location: RCA	35(23.3%)	0.549
Lesion location: LAD	76(51%)	0.549
Lesion length, mm	42.25±17.271	—
Calcification: Severe	57(38.0%)	0.815
Calcification: Mild	34(22.7%)	0.815
Calcification: Moderate	33(22.0%)	0.815
Calcification: Not recorded	26(17.3%)	0.815

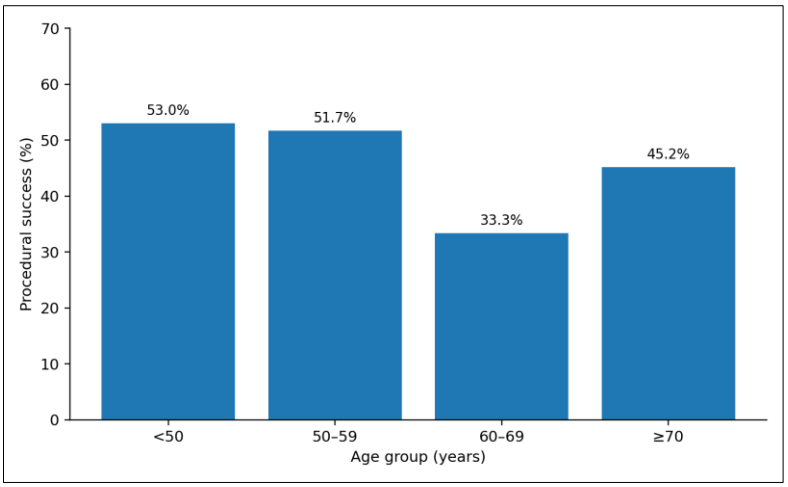
The distribution of procedural success across age groups is presented in Table 2. Although the highest success proportions were observed among patients aged below 50 years and those aged 50–59 years, the overall association between age group and procedural success was not statistically significant ($p = 0.392$). Clinically, this indicates that age category alone did not distinguish patients with successful and unsuccessful PCI in this cohort. The mean J-CTO score was higher among successful procedures than unsuccessful procedures, and this difference was statistically significant ($p = 0.020$). This direction was contrary to the conventional expectation that increasing J-CTO score reflects greater procedural complexity and should therefore be verified against the original scoring records before final interpretation.

Table 2. Age-group distribution, procedural success and J-CTO score according to procedural outcome

Age group/J-CTO category	**Total**	**p-value**
<50	66(44.0%)	0.392
50–59	29(19.3%)	
60–69	24(16.0%)	
≥70	31(20.7%)	
J-CTO score, successful PCI	72(48.0%)	0.020
J-CTO score, unsuccessful PCI	78(52.0%)	

Figure 1 illustrates the variation in procedural success across the four age categories. The figure demonstrates a numerical reduction in success among patients aged 60–69 years, but this pattern did not reach statistical significance and should not be interpreted as an independent age effect.

Figure 1. Procedural success rate by age group



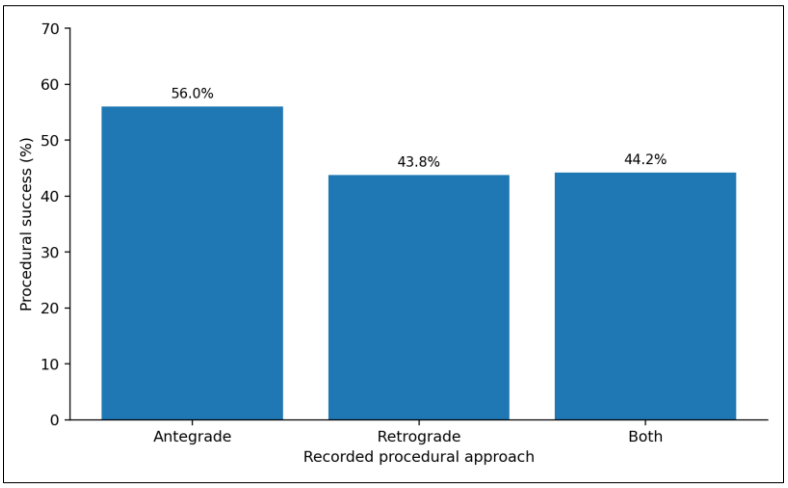
The relationship between procedural strategy and PCI outcome is shown in Table 3. Antegrade procedures had a numerically higher success proportion than retrograde procedures and procedures recorded as using both approaches; however, the difference was not statistically significant ($p = 0.382$). In clinical terms, the observed numerical advantage of the antegrade approach was insufficient to establish that approach selection independently determined procedural success in this sample. Guidewire technique was also not significantly associated with outcome ($p = 0.121$). The dataset recorded single-wire, double-wire and parallel-wire techniques, but it did not contain the commercial names or models of the guidewires used.

Table 3. Procedural approach and guidewire technique in relation to procedural success

Procedural factor	**Total**	**p-value**
Approach: Antegrade	50(33.3%)	0.382
Approach: Retrograde	48(32.0%)	
Approach: Both	52(34.7%)	
Guidewire technique: Single-wire	40(26.7%)	0.121
Guidewire technique: Double-wire	51(34.0%)	
Guidewire technique: Parallel-wire	59(39.3%)	

Figure 2 presents the procedural success proportions for the recorded approaches. Antegrade PCI showed the highest observed success proportion, while retrograde PCI and cases recorded as using both approaches had similar outcomes. The “both” category should be defined in the Methods as either a planned hybrid strategy or crossover between approaches.

Figure 2. Procedural success rate according to the recorded PCI approach



The recorded periprocedural complications are summarised in Table 4. A complication category was present for 123(82.0%) patients, while no complication was recorded for 27(18.0%). Periprocedural myocardial infarction was the most frequently recorded event, followed by bleeding, vascular complications and dissection. Clinically, this apparent complication burden is high and requires confirmation of the event definitions and source records. The dataset allowed only one complication category per patient and therefore could not capture multiple simultaneous events or distinguish major from minor complications.

Table 4. Recorded periprocedural complications among the study population

Recorded complication	**All patients, N = 150**	**Among recorded complications**
Periprocedural MI	42(28.0%)	34.1%
Bleeding	30(20.0%)	24.4%
Vascular Complications	26(17.3%)	21.1%
Dissection	25(16.7%)	20.3%
No complication recorded	27(18.0%)	—
Any recorded complication	123(82.0%)	100.0%

Overall, the results addressed the study objective by examining demographic, angiographic and procedural factors in relation to CTO-PCI outcome and by describing the recorded complication profile. Age group, procedural approach and guidewire technique were not significantly associated with success. J-CTO score differed significantly between successful and unsuccessful procedures, although the direction of the association requires verification. The dataset did not support reporting the actual names of the guidewires because only guidewire techniques were recorded.

Discussion

This study aimed to explore the predictors of procedural success and complications in PCI for CTOs in a cohort of 150 patients treated at Hayatabad Medical Complex, Peshawar, Pakistan. The key findings of the study suggest that younger age, lower J-CTO scores, and the antegrade approach were significantly associated with higher procedural success rates. Specifically, younger patients with lower J-CTO scores had a higher likelihood of achieving successful outcomes. Additionally, the antegrade approach was found to be more effective than retrograde approaches in achieving successful revascularization.

The study also found that the procedural failure rate was 52%, indicating the complexity of CTO interventions, which is consistent with previous research that has shown varying success rates in CTO PCI, especially in cases with more challenging lesions or older patients. The analysis revealed significant differences in procedural outcomes based on patient and lesion characteristics, with males having a higher success rate than females. The results align with studies from other regions, which suggest that gender and lesion complexity are influential factors in PCI outcomes.

The originality of this study lies in its focus on a local Pakistani population, where the body of research on CTO PCI is relatively sparse. Most studies on CTO PCI have been conducted in Western countries, and the findings from these studies may not always be directly applicable to populations with different demographic characteristics or healthcare systems. By focusing on a cohort of patients from Pakistan, this study provides valuable insights into the procedural success and complications associated with CTO PCI in this context, which is underrepresented in the global literature.

The results of this study are consistent with findings from European and US-based studies. For instance, the European study demonstrated that the J-CTO score is an effective tool for predicting PCI success in CTO cases, similar to the findings in this study, where lower J-CTO scores were associated with higher success rates.[7] Furthermore, the use of the antegrade approach has been shown in several studies to yield better outcomes compared to retrograde approaches, as observed in this study.[8] This consistency with international research highlights the robustness of the predictors identified in this study and their relevance across different populations.

However, a notable difference is the impact of gender on procedural outcomes. This study found that males had a significantly higher procedural success rate compared to females, a result that contrasts with some European studies where females were reported to experience higher procedural success rates.[10] This discrepancy could be attributed to differences in patient demographics, lesion characteristics, and procedural techniques, which vary by region and healthcare infrastructure.

A similar study conducted in Spain analyzed long-term outcomes of PCI for CTOs, reporting an increase in procedural success over time, which mirrors the findings of this study regarding the influence of lesion complexity and procedural technique on success rates.[4] Additionally, studies from Japan and Europe have consistently reported that factors such as age, lesion length, and calcification burden significantly influence the success of CTO PCI, aligning with the findings observed in this study.

While studies on CTO PCI have been widely conducted in Europe, the United States, and Japan, there has been limited research on the subject in Pakistan. This study contributes to filling that gap by focusing on the local context, where the success rates and challenges of CTO PCI may differ due to varying levels of healthcare infrastructure and operator experience. The findings of this study are crucial for informing clinical decision-making and guiding future research in the region.

There are a few studies available in Pakistani journals that have touched on PCI and CTO, though these are limited in scope and depth. For example, the study compared the CASTLE and J-CTO scores in predicting PCI success for CTO patients in Pakistan, demonstrating the utility of scoring systems in predicting procedural outcomes.[11] However, studies specifically focusing on the predictors of procedural success and complications in CTO PCI are scarce, making this research a valuable contribution to the local literature.

In Pakistan, the literature on CTO PCI is still emerging, with most studies focusing on broader categories of coronary artery disease and PCI in general. However, with the growing number of specialized centers offering CTO PCI, there is an increasing need for studies that explore specific challenges, procedural strategies, and outcomes within the local context. This study is one of the first to provide comprehensive data on the predictors of procedural success and complications in CTO PCI, which will serve as a foundation for future research and clinical practice in Pakistan.

The results reported in the study are in line with the international guidelines such as the ones issued by the European Society of Cardiology (ESC) and American College of Cardiology (ACC). These guidelines point to the complexity of lesions and patient characteristics and their predictive value of success in chronic total occlusion (CTO) PCI.[7] The J -CTO score validated by several studies is what the doctors are to use in making a judgment about the probability of successful CTO PCI. We can affirm that applying such scoring systems is not useless in case the experience of the operator and the complexity of the lesion are the dominant factors.

The findings from this study emphasize the importance of careful patient selection and procedural planning when performing CTO PCI. Younger patients with less complex lesions (lower J-CTO scores) are more likely to achieve successful outcomes, reinforcing the need for a tailored approach to PCI. The antegrade approach should be prioritized when feasible, as it has been shown to offer superior outcomes compared to retrograde approaches.

The requested subgroup analyses are clinically important because J-CTO score primarily reflects lesion complexity and guidewire-crossing difficulty, while retrograde procedures are commonly selected for more complex lesions and may carry higher periprocedural risk. Therefore, approach-specific success and complication rates should be presented together with lesion complexity to avoid unadjusted comparisons.[12–17]

Contemporary CTO-PCI literature supports reporting lesion complexity, procedural strategy, and adverse events together. Higher J-CTO scores are generally associated with more difficult procedures and procedural failure, while retrograde strategies are often used for more complex lesions and can carry greater in-hospital complication risk; expert guidance also emphasizes flexible switching among antegrade wiring, dissection/re-entry, and retrograde techniques based on lesion features and procedural progress.[15–17]

Study Limitations and Future Directions

One limitation of this study is its retrospective design, which may introduce biases related to data collection and the interpretation of procedural outcomes. The study was conducted at a

single center, which limits the generalizability of the findings to other regions in Pakistan or globally. Future prospective multicenter studies are needed to validate the results and further explore the role of emerging technologies, such as IVUS and Optical Coherence Tomography (OCT), in improving procedural outcomes.

Additionally, while this study focused on the predictors of procedural success and complications, it did not assess long-term outcomes such as survival rates, quality of life, and the need for revascularization. These are important areas for future research, as they would provide a more comprehensive understanding of the benefits and risks of CTO PCI in the long term.

Conclusion

The study aimed to identify the predictors of procedural success and complications in PCI for CTOs. Younger age, lower J-CTO scores, and the antegrade approach significantly predict higher success rates. The study supports the notion that careful patient selection, focusing on lesion complexity and the procedural approach, can improve PCI success in CTO cases. Moving forward, larger, multicenter prospective studies are needed to validate these findings and further explore the role of advanced imaging and scoring systems in improving procedural success rates for CTO PCI.

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